DETERMINATION OF SAMPLE SIZE REQUIREMENTS TO ANALYZE THE AGE STRUCTURE OF THE B.C. CHINOOK CATCH

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ABSTRACT

Palermo, R.V. 1984. Determination of Sample Size Requirements to Analyze the Age Structure of the British Columbia Chinook Salmon Catch. Can. Tech. Rep. Fish. Aquat. Sci. 1335-vii-11p.

Constraints due to fish processing plant grading procedures do not allow a random sampling of landed catch. Once landed at the fish plant, the chinook salmon are separated according to flesh colour and size, or some combination of these. This pre-sampling sorting complicates the sampling procedure, rendering it difficult to adequately sample the fish in each stratum in an unbiased manner. The sampling methodology presented in this report is a representative and unbiased design based on estimates of variances and proportion of catch in each fishery specific strata. This method is a combination of proportional allocation and stratification for continuous data using user specified error bounds.

Key Words: Proportional Allocation, Stratification for continuous data, error bounds, chinook salmon

RÉSUMÉ

Palermo, R.V., 1984. Determination of Sample Size Requirements to Analyze the Age Structure of the British Columbia Chinook Salmon Catch. Can. Tech. Rep. Fish. Aquat. Sci 1335-vii-11p.

Les contraintes liées aux procédures de triage du poisson dans les usines de transformation ne permetent par un échantillonnage aléatoire des débarquements. Une fois transporté à l' usine, le saumon quinnat est trié selon la taille et la couleur de la chair, ou une combinaison de ces critères. Ce triage, effectué avant l'échantillonnage, complique la procédure expérimentale. Il est donc difficile d'échantillonner sans biasis le poisson de chaque strate. La méthode de sondage présentée dans le présent rapport est représentative; sa conception non biaisée est basée sur des estimations de variances et sur une proportion de la prise dans chaque strate particulière de la pêché. Cette méthode combine la répartition proportionnelle et la stratification de données aléatoires à l'aide de limites d'erreur précisées par l'utilisateur.

Mots-clés: répartition proportionnelle, stratification de données aléatoires, limites d'erreur, saumon quinnat

Introduction

The required sample size needed to determine the age composition of the chinook catch in each B.C. fishing area presents serious problems. Ideally, representative random samples from the catch in each area by gear, and time, should be taken. Unfortunately this is not possible because sampling is limited to select landing locations. Further, constraints are placed by the method of grading the catch at each landing location. These grade strata are dictates of market demand and therefore impose a unique distribution on sampling categories that may change yearly in response to shifts in market demands. Consequently, the sampling methodology should be flexible in response to such changes, maintaining representative data collection across all strata. At the same time, the sampling design should be optimal in both statistical need and resource allocation to minimize costs.

Once landed at the fish plants, the chinook salmon are separated according to flesh colour and size, or some combination of these. In the Net Fisheries, colours are mixed and the grades are determined by fish weight. The first grade are fish < 5 lb. and the second, > 5 lb.. Northern and Central Troll Fisheries grade by colour (reds and whites) and fish weight (small, medium, and large). The fish weight categories are 6-8 lbs, 8-12 lbs, and > 12 lbs. Georgia Strait Troll Fisheries are graded similarily except a new fish weight category, tiny (fish < 6 lbs.) is added. West Coast Troll Fisheries are mixed by colour and graded by weight in classes of small, medium, and large, based on the fish weight categories of Northern and Central Troll. This pre-sampling sorting complicates the sampling process, rendering it difficult to adequately sample the fish in each stratum in an unbiased manner. Knowledge of variances and proportion of catch contribution in each stratum (which are different) are needed to assess an unbiased sampling scheme.

The sampling methodology presented in this report is a representative and unbiased design addressing the particular question posed by management biologists; What is the age composition by area, gear, and time of the British Columbia chinook catch? The area strata is defined as the Management Fishing areas of B.C., gear strata are troll and net, and time stratum is by week. The different strata levels are presented in Figure 1.

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Methodology

For practical considerations, the B.C. coast was divided into 11 strata that are combinations of area and gear. These area-gear strata are presented in Table 1 along with their respective average catch for the years 1976-1981 (Starr, 1981, Personal Comm.) Figure 2 presents the combined strata schemes.

Letting i= 1 to 11 to represent area-gear strata then;

$$\sum_{i=1}^{11} \bar{C}_i = \bar{C}_T \qquad (1)$$

where $\bar{C}_i$ is the mean catch per stratum and $\bar{C}_T$ is the mean yearly total catch.

Letting t = 1 to tn represent weekly time strata, then;

$$\sum_{t=1}^{t_n} \bar{C}_{it} = \bar{C}_i \qquad (2)$$

(sum of weekly catches by area-gear = total catch by area-gear)

and

$$C = C \qquad (3)$$

Letting $\bar{P}r_{it}$ be the proportion of red fish per area-gear per week then the total mean number of red fish $\bar{C}_{iR}$ is:

$$\sum_{t=1}^{t_n} \left[P_{rit} \cdot \bar{C}_{it} \right] = \bar{C}_{iR} \qquad (4a)$$

Similarily the total mean number of white fish $\bar{C}_{iw}$ is:

$$\sum_{t=1}^{t_n} \left[(1-P_{rit}) \bar{C}_{it} \right] = \bar{C}_{iw} \qquad (4b)$$

and

$$\bar{C}_{iRt} + \bar{C}_{iwt} = \bar{C}_{it} \qquad (5)$$

Letting $\bar{P}gr$, where g= 1 to 3 represent the proportion of red fish that are grades 1 to 3 (size) and $\bar{P}gw$ represent the proportion of white fish in the three grades, then;

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$$\sum_{t=1}^{t_n} \sum_{g=1}^{3} \left[\bar{P}_{gr_t} \cdot \bar{P}_{ri_t} \cdot \bar{C}_{i_t} \right] = \bar{C}_{i_A} \qquad (6a)$$

and

$$\sum_{t=1}^{t_n} \sum_{g=1}^{3} \left[\left(\bar{P}_{gw_t} \right) \left(1 - \bar{P}_{ri_t} \right) \left(\bar{C}_{i_w} \right) \right] = \bar{C}_{iw} \qquad (6b)$$

where $\sum_{g=1}^{3} \bar{P}_{gr} = 1$ and $\sum_{g=1}^{3} \bar{P}_{gw} = 1$

Combining colour and fish weight as a stratum, then $\left[\bar{P}gw \cdot \bar{P}gr\right] = \bar{w}g$

and

$$\sum_{i=1}^{6} \left[\bar{W}_{gi} \cdot \bar{C}_{i_t} \right] = \bar{C}_{i_t} \qquad (7)$$

where

$$\sum_{i=1}^{6} \bar{W}gi = 1$$

and each $\bar{W}_{gi} \cdot \bar{C}_{i_t}$ is the proportion of the catch from the area-gear stratum in the colour-size stratum. If the statistical weights $\bar{W}g_i$ remain constant throughout the fishing season in each appropriate stratum, then the analysis is straight forward. Table 2 presents a trivial example of the proportional allocation.

The sample size required by strata was calculated using the method of Stratification for continous data (Cochran 1977), Scheaffer et al, 1979). Letting Nh = $E(\bar{C}i)$, the expected catch in the stratum, and h= the number of strata, then the sample size n is calculated by;

$$n_i = n(wi) \qquad i=1...h \qquad (8)$$

where $$w_i = N_i \cdot S_i \left(\sum_i (N_i \cdot S_i) \right) \qquad i=1...h \qquad (9)$$

and S_i is the standard error of the variable in stratum i.

Then

$$n = \frac{\sum_i \left(N_i^2 \cdot S_i^2 / w_i \right) \qquad i=1...h}{N_T^2 \, V + \sum_i \left(N_i \cdot S_i^2 \right)} \qquad (10)$$

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where $N_T = \sum_{i}^{h} N_i \qquad i=1...h$

and $V = (d/t)^2$

where d= the margin of error and t= the normal deviate corresponding to the allowable probability that the error will exceed the desired error margin.

Table 5 demonstrates this method using the data in Table 2. where S = 1 for all i, d = .05 and t = 1.96.

Analysis

As each catch is graded differently, it was necessary to lump common groups. Figure 3 presents the way area-gear and grades were considered in the analysis. The Net fisheries share a common grading structure, but the Troll Fisheries catch is graded differently as indicated earlier. J. Thomas, (1981), provided the proportion of the catch falling into each appropriate stratum for the 1981 Catch (Tables 3 and 4). The variance for each stratum was then calculated. This variance is the fish weight variance, as fish are graded by weight. Because fish weight and age are co-related, and fish weight is the select criteria (size), we are assuming that there is a covariance between age and fish weight, a not unreasonable assumption. For example, we expect a greater variance in the > 5 lbs. group in Net fisheries than in the < 5 lbs. group, and expect a wider range of ages in the former than the latter.

The data for each group was entered in the Apple micro computer via Visicalc and the appropriate model to calculate sample size for each stratum was then constructed. The advantage of using Visicalc software for this method is that we can change the error bounds of the estimates and examine the effects in an interactive way. For each stratum the expected proportion of catch falling in that stratum was first calculated (ie. $E(\bar{C}_i)$), by the method of proportional allocation (equations 1 to 7). The actual sample sizes where then calculated using equations 8 to 10 from the data in Tables 3 and 4.

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The results of the analysis and recommended sample sizes are presented in Table 6. The overall season sample size, given the statistical criteria in Table 6, is 27813. Of these 1207 are from Georgia Strait Troll, 3063 from South West and North West Troll, 9498 from Northern and Central Troll, and 14045 from the various net fisheries. These results seem reasonable given the nature of the fisheries. The validity of this method and the estimates will be tested using the sample data from the 1982-1984 biosampling program.

References

Cochran, W.G. (1977) Sampling Techniques, 3rd Edition, J. Wiley & Sons

Scheaffer, R.I. W. Mendenhall, L. Ott (1979) Elementary Survey Sampling, 2nd Edition, Duxbury Press.

Starr, P 1976 - 1981 Average Catch Statistics, Personal Communication

Thomas, J Proportional Catch Data, J.E. Sager & Associates, Personal Communication

Appendix 1 - Mathematical Symbols

$\bar{C}$	mean catch .
i	subscript denoting strata
h	subscript denoting total number of strata
T	subscript denoting a total
t	subscript denoting week
tn	total number of weeks (sampling period)
$\bar{P}$	mean proportion
R	subscript denoting red fish
W	subscript denoting white fish
g	subscript denoting grade
$\bar{w}$	mean proportion - colour weight combination
n	sample size
w	statistical weights
N	population total
S	standard deviation
d	error bound
t	normal deviate, t distribution

Appendix 2 - Defenitions

NN	Northern Net
NGN	Northern Gill Net
JSN	Johnston Strait Net
FRGN	Fraser River Gill Net
JFN	Juan de Fuca Net
WLN	West Coast Net
NTR	Northern Troll
CTR	Central Troll
NWTR	Northwest Troll
SWTR	Southwest Troll
GSTR	Georgia Strait Troll

FIG. 1

STRATA SCHEMES

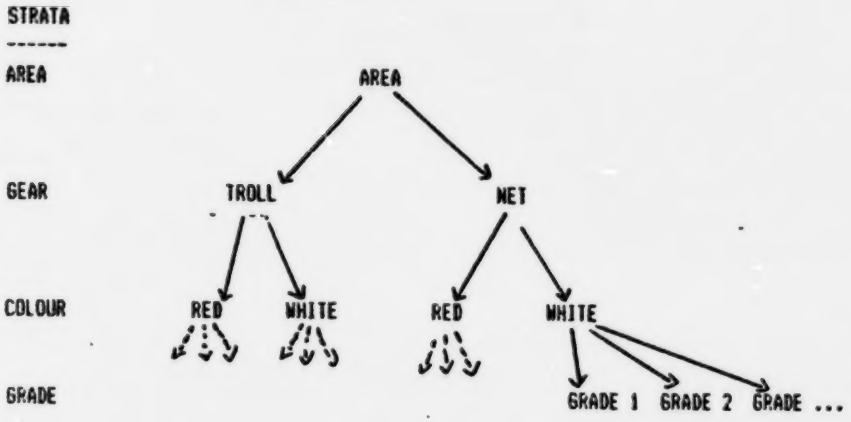


FIG. 2

STRATA SCHEME

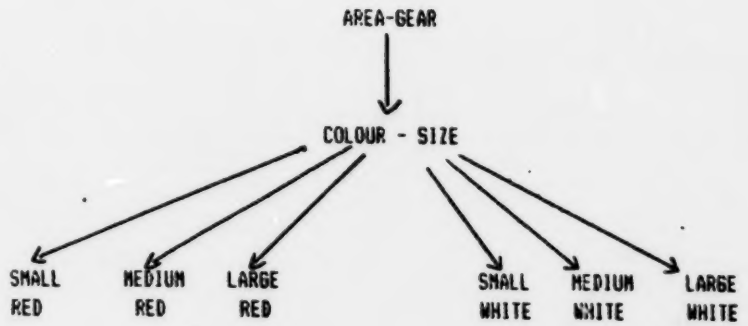
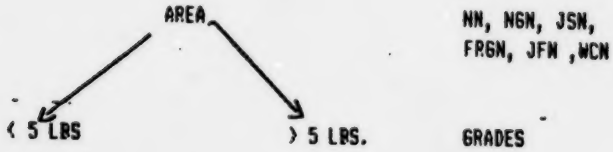


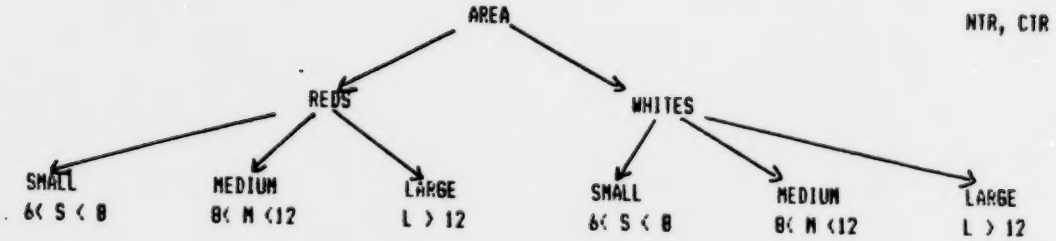
FIG. 3

STRATA SCHEMES BY FISHERY

NET FISHERIES



TROLL FISHERIES



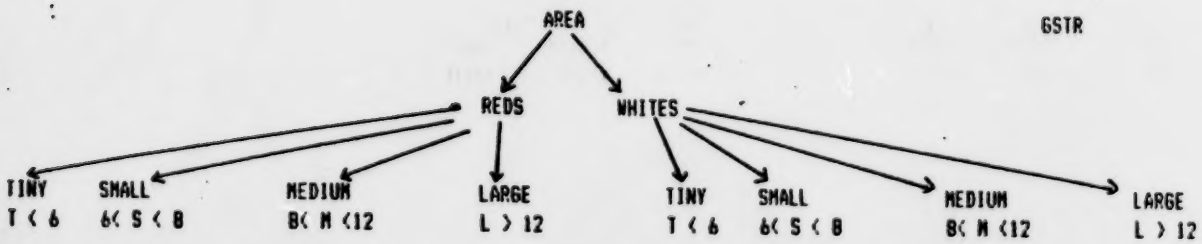


TABLE 1

AREA-GEAR COMBINATIONS AND CATCH

AREA-GEAR	AREA	MEAN CATCH (1976-1981)
NTR	1-5	156253
CTR	6-11, 30	95507
GSTR	12-20	256510
SWTR	21-24	449868
NWTR	25-27	87527
SUB TOTAL TROLL		1044865
NN	1-8	78490
NGN	3-10	35891
JSN	12-19	60405
FRGN	29	56276
JFN	20	35453
WCN	21-27	51526
SUB TOTAL NET		310041
MEAN TOTAL CATCH		1354906

TABLE 2

EXAMPLE PROPORTIONAL ALLOCATION

$P_{r_{i2}}$ = .7 $\quad \overline{C}_{i_2}$ = 1000

$P_{w_{i2}}$ = .3

$P_{r_{g1}}$ =	.02	$P_{w_{g1}}$ =	.05
$P_{r_{g2}}$ =	.68	$P_{w_{g2}}$ =	.42
$P_{r_{g3}}$ =	.3	$P_{w_{g3}}$ =	.53
SUM =	1		1

$W_j = P_{r_{i2}} * P_{r_{gj}}$ J=1..3

$W_j = P_{w_{i2}} * P_{w_{gj}}$ J=4..6

						$E(\overline{C}_i)$
W_1	=	.7	* .02	=	.014	14
W_2	=	.7	* .68	=	.476	476
W_3	=	.7	* .3	=	.21	210
W_4	=	.3	* .05	=	.015	15
W_5	=	.3	* .42	=	.126	126
W_6	=	.3	* .53	=	.159	159
				SUM =	1	1000 = $\overline{C}_{i_2}$

TABLE 3

GRADE PROPORTIONS NET FISHERIES

AREA-GEAR	) 5 LBS	(5 LBS
NN	.953	.047
NGN	.677	.323
JSN	.426	.574
FRGN	.92	.08
JFN	.301	.699
WCN	.2	.8

TABLE 4

GRADE PROPORTIONS TROLL FISHERIES

	REDS				WHITE			
	TINY	SMALL	MEDIUM	LARGE	TINY	SMALL	MEDIUM	LARGE
NTR		.189	.212	.598		.017	.018	.053
CTR		.212	.235	.437		.032	.04	.085
GSTR	.39	.353	.057	.034	.085	.063	.011	.007

	MIXED COLOUR		
	SMALL	MEDIUM	LARGE
SWTR	.483	.296	.221
NWTR	.276	.287	.437

TABLE 5

EXAMPLE PROPORTIONAL ALLOCATION CALCULATION

H	N_i	S_i	$N_i S_i$	W_i	$N_i^2 S_i^2 / N_i$	$N_i S_i^2$	$n_i N_i$
1	14	1	14	.014	14000	14	8
2	476	1	476	.476	476000	476	288
3	210	1	210	.21	210000	210	127
4	15	1	15	.015	15000	15	9
5	126	1	126	.126	126000	126	76
6	159	1	159	.159	159000	159	96
SUM =	1000	6	1000	1	1000000	1000	604

T = 1.96

D = .05

$V = (D/T)^2$ = 6.508E-4

$N_i^2 * V$ = 650.7705

$N_i^2 * S^2$ = 1000

$N_i^2 S_i^2 / N_i$ = 1000000

n_i = 605.7777 (TOTAL SAMPLE SIZE)

$n_i N_i$ = SAMPLE SIZE BY GRADE

TABLE 6

RECOMMENDED SAMPLE SIZE - NET FISHERIES (ERROR BOUND = .1 (10%) AT T=1.96 (95%))

AREA-GEAR	) 5 LBS	(5 LBS
NN	223	4553
NGN	573	1202
JSN	1149	853
FRGN	294	3382
JFN	620	266
WCN	760	190
SUB TOTAL	3619	10446

TOTAL NET FISHERIES 14065

RECOMMENDED SAMPLE SIZE - TROLL FISHERIES (ERROR BOUND = .1 (10%) AT T=1.96 (95%))

	REDS				WHITE			
	TINY	SMALL	MEDIUM	LARGE	TINY	SMALL	MEDIUM	LARGE
NTR		100	366	4970		9	31	518
CTR		74	248	2613		11	42	500

SUB TOTAL= 9498

	MIXED COLOUR		
	SMALL	MEDIUM	LARGE
SWTR	217	400	1694
NWTR	24	75	653

SUB TOTAL= 3063

(ERROR BOUND =.05 (5%) AT T=1.96 (95%))

	REDS				WHITE			
	TINY	SMALL	MEDIUM	LARGE	TINY	SMALL	MEDIUM	LARGE
GSTR	263	238	115	390	57	42	22	80

SUB TOTAL= 1207

TOTAL TROLL FISHERIES = 13768

TOTAL COASTAL SAMPLE SIZE= 27813